MEMORANDUM

INTERMOUNTAIN POWER SERVICE CORPORATION

TO: TO: Dennis K. Killian

FROM: FROM: Gerald K. Hintze

DATE: January 5, 2011

SUBJECT: Review of boiler and soot blower design criteria concerning future coal quality issues

Engineering Services has reviewed the boiler design, pulverizer capacity and existing soot-blower capability for adequacy in handling lower coal-quality issues in the future. The results of this study follow.

Summary

Boiler Design

No modifications to boiler ancillary equipment (pulverizers, air heaters, soot blowers, etc.) are needed if we hold to coal blends within the original design specifications. However, primary air flow, soot-blow frequency, and pulverizer throughput will increase as coal quality decreases. Resultant damage to air heaters, ductwork, pulverizers, burners, and boiler internals due to these increases is to be expected.

The boiler was designed to burn primarily Utah coals with as much as a 50% blend of Type "F" coal. The rated unit load of 950 MW can be met with this blend with 7 pulverizers at 85% feeder speed. If the blend coal is Powder River Basin coal (PRB), the blend fraction is cut to 35% due to the lower BTU content of the PRB coal. Slagging potential, furnace corrosion and materials handling issues (dusting) will increase with PRB coals.

Pulverizer Capacity

If the blend of Type "F" coal or PRB coal is increased above that stated above, pulverizer capacity will have to be increased due to the lower BTU content of the blend. Capacity can be increased by either adding pulverizers, replacing existing pulverizers with higher capacity models, upgrading existing pulverizers, running 8 pulverizers when available, or a combination of the above.

Soot Blower Capability

Since original construction, several soot blowers have been added to each unit to accommodate specific cleaning needs, and plant uprate modifications. Specifically, the following blowers have

been added:

- two platen long retractable soot-blowers added
- four horizontal reheat extended lances added
- eight economizer extended lances added
- nine wall blowers removed to make room for the over-fire air installation

If the blend of Type "F" or PRB coal is increased above the design case stated above, more soot blowers will likely have to be added in order to maintain heat absorption in the furnace and pendant sections of the boiler. With PRB coals, water canons and or water lances will be needed in the furnace and the frequency of soot blows will increase. Accelerated soot blower and flyash erosion can also be expected.

A detailed treatment of this study is presented below.

Coal Quality

The design range of coal heating value for Intermountain Power is 10,500 to 12,100 BTU/lb. The Utah performance coal is 11,010 BTU/lb. The unit was designed for a blend not to exceed 50% coal "F" specified at 9962 BTU/lb. With our units, a 50% blend of Utah performance coal and coal "F" would put us around 407 tons or 85% feeder speed on the 7 pulverizers in-service to maintain full load. With an increase in the blend percentage, 950 megawatt load capacity would not be achieved. The boiler design also has a limit of 22% moisture in the coal. Greater moisture would need a higher primary air heater air outlet temperature than the 540 °F available. To burn higher moisture coals (such as PRB) would involve a capital project to install new primary air heater baskets and decrease primary air heater leakage.

The historical coal heating value weighted average is around 11,831 BTU/lb with ranges from a low of 10,752 BTU/lb in December 2004 to a high of 12,246 BTU/lb in July 1989. A typical breakdown of mines are given in table 1. To maintain the units at 950 megawatts a heating value of 10,600 BTU/lb coal blend or greater is needed due to pulverizer capacity (7 pulverizer configuration @ 85% average coal feeder speed). The average heating value drops to 9300 BTU/lb changing operational mode to eight pulverizers (average 85% coal feeder speed).

For PRB coals or other lower BTU coals in the 8300 BTU/lb range, a blend of 35% or less is needed with the 11,831 BTU/lb (historical average)to maintain full load with 7 pulverizers.

Soot blowers

Since original construction the following soot-blowers modifications were made for boiler increased cleanliness coverage, to address problem areas or boiler modifications per unit:

1) two platen long retractable soot-blowers
2) four horizontal reheat extended lances
3) eight economizer extended lances
4) nine wall blowers removed to make room for the over-fire air installation.

Since start-up of the units, a check of all soot-blowers and the areas cleaned by these soot-blowers are included in the regular boiler inspection. Tubes in the soot-blower zones are inspected closely for any signs of metal loss due to fly-ash erosion, soot-blower steam erosion and rubbing of adjacent tubes. Metal loss can occur due to direct impingement of the high pressure steam. Corrective actions include reducing the blowing pressure (if cleanliness has been achieved), realigning the soot-blower elements, installing tube shields in affected areas, and boiler tube alignments.

The amount of soot-blower cleaning required depends on the unit generation, the number and magnitude of load changes, the type of fuel burned and the total combustion air required. Since 1989 the ash fusion weighted average temperature has been around 2244 °F. This is slightly in the high classification using the slagging index as a reference. Several coals burned are routinely in the severe classification (<2100 °F) but are offset by blending with other coals. Increasing the use of low fusion coals would have to be offset by increased blowing frequency from the once per shift present requirement. Increased blowing pressures would be required as fouling and slagging became more of an issue.

In the extreme case, additional soot-blowers would need to be installed and the use of water lances in the water wall and platen areas would be required to keep the furnace box clean. Presently, 54 long retractable, 28 extended, and 45 wall blowers are installed on each unit. There are also 30 long retractable, 8 extended, and 66 wall blower future soot blower locations.

Table 1
Coal sampled June 2005

Mine	% of total	HHVC BTU/lb	Slagging Index *RS
Genwal	15.29	11,754	2,272
SUFCO	26.92	11,402	2,076
Andalex	5.81	12,624	2,121
Arch	22.84	12,267	2,376
West Ridge	7.66	12,641	2,149
Coastal	7.59	12,055	2,368
Arch spot	1.82	10,993	2,437
Andalex spot	5.84	12,850	2,127
Black Butte	6.24	9,575	2,084
Weighted	100.	11,832	2,215

*RS	classification
If > 2250 F	medium
2250 to 2100 F	high
< 2100 F	severe

If you have questions regarding this report, please call Garry Christensen at Extension 6486.

GC:

THIELSCH ENGINEERING, INC.

195 Frances Avenue
Cranston, Rhode Island 02910-2211
Tel. (401) 467-6454
Fax. (401) 467-2398
khackett@thielsch.com

December 26, 2007

Mr. Gary Christensen
Performance Engineer
Intermountain Power Service Agency
850 West Brush Wellman Road
Delta, UT 84624-8546

SUBJECT: Metallurgical Evaluation of Coal Burner Tip Failure

Dear Mr. Christensen:

Thielsch Engineering Report No. 12453 covers our examination of the failed coal burner tip from the No. 2 Boiler at the Intermountain Power facility in Delta, Utah.

Please note that the material received from Intermountain Power and any specimens generated for this project will be disposed of after 30 days (January 26, 2007) unless we are notified otherwise. Please contact me if you would like to make alternate arrangements.

Very truly yours,

THIELSCH ENGINEERING, INC.

Katherine Hackett
PED Communications Specialist

kh/60070068

cc: Julie Brown

THIELSCH ENGINEERING, INC.

195 Frances Avenue
Cranston, Rhode Island 02910-2211
Tel. (401) 467-6454
Fax. (401) 467-2398

December 26, 2007

Mr. Gary Christensen
Performance Engineer
Intermountain Power Service Agency
850 West Brush Wellman Road
Delta, UT 84624-8546

SUBJECT: Metallurgical Evaluation of Coal Burner Tip Failure

Dear Mr. Christensen:

Enclosed are two copies and a CD containing an Adobe Acrobat (.pdf) file of Report No. 12453 covering our examination of the failed coal burner tip from the No. 2 Boiler at the Intermountain Power facility in Delta, Utah.

Thielsch Engineering performed a metallurgical evaluation of a coal burner tip that had failed in service at the Intermountain Power facility in Delta, Utah. The results of this evaluation indicate that the failure of the burner tip was due to the improper chemical composition of the casting which was susceptible to carbide precipitation, sigma phase embrittlement and cracking when exposed to the operating temperature of between 980°F and 1505°F. Preferential and localized erosion of the burner tip had also contributed to the failure.

Very truly yours,

THIELSCH ENGINEERING, INC.

Ara Nalbandian

Ara Nalbandian, P.E.
Vice President of Engineering

Enclosures

kh/60070068

THIELSCH ENGINEERING, INC.
195 FRANCES AVENUE
CRANSTON, RHODE ISLAND 02910

METALLURGICAL EVALUATION OF
COAL BURNER TIP
SUBJECT TO
EMBRITTLMENT AND EROSION
INTERMOUNTAIN POWER SERVICE CORPORATION
DELTA, UTAH

Ara Nalbandian
Ara Nalbandian, P.E.

Roger Kalikian
Roger Kalikian, P.E.

December 14, 2007 Report No. 12453

INTRODUCTION

The Intermountain Power Service Agency provided Thielsch Engineering with a 20" OD coal burner tip that had failed in service at their facility in Delta, Utah. Thielsch Engineering was requested to perform a metallurgical evaluation to determine the cause(s) of the failure.

BACKGROUND INFORMATION

The boiler from which this burner was removed has seven burners, with six in service. This boiler is used for base-line operation. The failed burner tip had been in service for approximately two years, or approximately 15,000 hours. The maximum intermediate and tip temperatures for this burner were reported to be 980°F and 1605°F, respectively, during its two years of service.

The burner tip was supplied by Advanced Burner Technologies, it was reported to have been fabricated from alloy steel produced in accordance with ASTM Specification A-297, Grade HE covering, "Steel Castings, Iron-Chromium and Iron-Chromium-Nickel, Heat Resistant, for General Application". The nominal wall thickness of the burner was reported to be 0.375". Under normal operating conditions, the burner was reported to have an expected service life of 4 years.

LABORATORY EXAMINATION

The burner tip submitted for metallurgical examination is shown in the as-received condition in Fig. 1. As part of the metallurgical examination of the burner tip, visual examination, dimensional measurements, chemical analysis and optical microscopy were performed to determine the failure mode and the overall condition of the burner tip.

Visual Examination

The six burner vanes were arbitrarily labeled 0°, 45°, 135°, 180°, 225° and 335° for ease of reference. Overall views of the outside diameter surfaces of the burner tip are shown in Figs. 2 through 4. Visual examination confirmed that there were multiple cracks, both longitudinal and transverse. Furthermore, the cracking had caused a segment of the burner vane labeled 180° to be completely detached from the burner. Visual examination also confirmed that the cracking had initiated at the locations marked 45°, 180° and 335°.

Close-up views of the inside diameter surfaces of the burner are provided in Figs. 5 through 7. Visual examination of the inside diameter surfaces confirmed that localized areas of the burner tip had undergone significant erosion wear.

Overall and close-up views of the detached segment are provided in Figs. 8 and 9. Significant thinning was apparent on this segment. Furthermore, it was apparent that at least some of the wear had occurred after the fracture. This is confirmed by the wear observed on the fracture surfaces (Fig. 8) and localized wear observed on the inside diameter surfaces adjacent to the cracks (Fig. 9).

Visual examination of the fracture surfaces confirmed that the fractures were typical of a brittle failure mode with no evidence of plastic deformation.

Dimensional Measurements

As part of the laboratory examination, dimensional measurements were performed on this burner. These dimensional measurements, which were limited to wall thickness determinations, are provided in Appendix A. The wall thickness values were recorded at six locations (Nos. 1 through 6), where erosion wear was observed during the visual examination. Additional wall thickness values were recorded at locations 2" above and 2" below the observed wear areas.

The results of the dimensional measurements confirmed that the erosion wear observed was highly localized. The wall thickness values at locations Nos. 1, 2, 3, 4 and 6 ranged from 0.081" to 0.145", a reduction of 62% to 79% from the reported nominal thickness of 0.375". The wall thickness value recorded at location No. 5 was 0.418", or 11% greater than the reported nominal thickness. Furthermore, thickness readings recorded 2" above and 2" below the wear areas did not reveal significant wear.

Wall thickness measurements were also recorded along the fracture edges of the detached segment (reference Appendix A). The wall thickness values ranged from 0.036" to 0.593", a variation of -90% and + 58% of the reported nominal wall thickness of the burner, providing further confirmation of the localized nature of the observed erosion wear. The wall thickness values along the fracture also confirmed that the reductions in wall thickness had not occurred due to plastic deformation.

Chemical Analysis

Segments were removed from the body of the burner and one of the plates welded to the burner for chemical analysis. The results of the chemical analyses, which are provided below, were compared to the chemical composition requirements of the reported specified material grade:

Element	Burner Plate	Sample No. 1	Sample No. 2	ASTM Specification A-297, Grade HE
C	0.24 %	0.58 %	0.47 %	0.20 - 0.50 %
Mn	0.51	0.56	0.86	2.00, max.
P	0.01	0.02	0.02	0.04, max.
S	0.01	0.01	0.01	0.04, max.
Si	1.72	2.62	2.69	2.00, max.
Cr	21.0	28.5	28.7	26.0 - 30.0
Ni	10.8	6.8	6.9	8.0 - 11.0
Mo	0.07	0.13	0.19	0.50, max.

The results of the chemical analyses confirmed that the burner had not been produced in accordance with the chemical composition requirements of ASTM Specification A-297, Grade HE covering, "Steel Castings, Iron-Chromium and Iron-Chromium-Nickel, Heat Resistant, for General Application". Specifically, the silicon content of the burner was significantly higher than the maximum allowable value of 2.00%. Furthermore, the nickel content of the burner was less than the allowable minimum value of 8.0%. The burner plate also did not conform to the chemical requirements of the specified material grade. Based on the values obtained, the burner plate conformed to the chemical composition requirements of ASTM Specification A-297, Grade HF.

Metallurgical Examination

Once the chemical composition of the burner was verified, a subsegment from the detached segment of the burner was examined by optical microscopy. This examination was performed to determine the cause of the failure and to identify the microstructural condition of the burner.

To facilitate the optical microscopy, the detached burner segment was cross sectioned at location "A-A". (Reference Fig. 8.) A subsegment was removed at the location of this cross section. The subsegment was then metallographically prepared. This involved being mounted in bakelite, surface ground, polished and etched using an etchant solution typically used to delineate the microstructure of stainless steels. Subsequent to the metallographic preparation, the subsegment was examined comprehensively at higher magnifications by optical microscopy.

The subsegment removed at cross section "A-A" through the fracture origin is shown at a magnification of 1X (one diameter) in Fig. 10. Rockwell B and C hardness determinations were made at the locations shown. The corresponding Brinell hardness values, provided in ( ), ranged from 304 BHN to 307 BHN in the burner, from 186 BHN to 199 BHN in the plate, and from 224 BHN to 229 BHN in the weld. The expected Brinell hardness value for a grade HF casting in the as-cast condition is approximately 200 BHN.

Photomacrographs (magnification 15X) of cross section "A-A" are provided in Fig. 11. Cross section "A-A" was examined comprehensively at higher magnifications and representative areas were selected to document conditions observed. These areas, identified as "A_2" to "A_{10}", are indicated on the photomacrographs.

Area "A_2", Fig. 12, was located on the plate that was welded to the burner. The microstructure consisted of austenite grains, typical for austenitic stainless steel.

Area "A_3", Fig. 13, was selected to illustrate the cracking observed on the burner-to-plate filet weld. The crack progression was transgranular in nature, indicative of fatigue. Localized recrystallization of the grains at the mating fracture surfaces was observed near the tip of the crack. This suggests that the two fracture surfaces may have come in contact with each other, with the subsequent exposure to elevated temperature causing the observed recrystallization of the grains. The microstructure at area "A_3" consisted of austenite grains, with a large amount of carbides at the grain boundaries.

Area "A_4", Fig. 14, illustrates the microstructure of the burner near the plate-to-burner filet weld. The microstructure in this area was dendritic, consisting of austenite (light matrix) and ferrite with carbide islands. Casting defects such as porosity, shrinkage voids or hot tears were not observed.

Areas "A_5" through "A_7", Figs. 15 through 17, respectively, illustrate the microstructure at the fracture surfaces. The fracture surfaces at and near the inside diameter of the burner were smooth and rounded, most likely due to erosion. Some localized cold work was observed near the outside diameter surfaces. Again the microstructure consisted of austenite (light matrix) and ferrite with carbide islands. Casting defects such as porosity, shrinkage voids or hot tears were not observed.

Area "A_8", Fig. 18, illustrates the other fillet weld in cross section "A-A". The microstructure observed in this area was similar to that at "A_8" and similar comments apply.

Area "A_9", Fig. 19, illustrates the inside diameter surface of the burner away from the fracture. The microstructure consisted of austenite (light matrix) and ferrite with carbide islands. Casting defects such as porosity, shrinkage voids or hot tears were not observed.

Cross section "A-A" was re-etched with a solution of sodium cyanide in an effort to delineate any possible carbides and/or sigma phase precipitates. The cross section was examined comprehensively by optical microscopy. Area "A_{10}", shown in Fig. 20, was selected to illustrate the observed precipitates (dark areas).

DISCUSSION

Heat resistant iron-chromium-nickel castings are typically specified in applications where service temperatures exceed 1200°F and may reach temperatures as high as 2400°F. Some of the materials selection considerations in high temperature applications include resistance to oxidation, cracking, warping, thermal fatigue and strength at the service temperature. Iron-chromium-nickel casting alloys typically will contain 18% to 32% Cr and 4% to 22% Ni and include the grades HD, HE and HF. A Specification commonly referred to in ordering iron-chromium-nickel castings is the ASTM Specification A-297 covering, "Steel Castings, Iron-Chromium and Iron-Chromium-Nickel, Heat Resistant, for General Application". Castings furnished in accordance with this Specification are expected to conform to the chemical composition requirements provided in Table 1 of the Specification, a copy of which is provided in Appendix B.

Iron-chromium-nickel alloys are susceptible to considerable hardening which can result in severe loss of ductility (embrittlement) after prolonged exposure to elevated temperatures. This embrittlement is caused by carbide precipitation and agglomeration at the grain boundaries as well as sigma phase precipitation.

The temperature range for sigma phase embrittlement to occur is mostly dependent on the chemical composition of the alloy and the resultant microstructure. The effect of nickel content on sigma phase formation is largely due to its ability to stabilize the austenite against ferrite formation and thus reduce the propensity for sigma formation. Increasing the nickel content also has the added benefit of increasing the high-temperature strength of iron-chromium alloys. Additions of silicon have the opposite effect. High silicon content promotes the formation of ferrite and contributes to the formation of sigma phase. It also lowers the impact and fatigue properties of iron-chromium-nickel alloys. Because of this, low nickel iron-chromium-nickel alloys have a maximum allowable silicon content of 2.00%, while higher nickel alloys have a maximum allowable silicon content of 2.50%.

Once embrittlement has occurred, the ductility of these alloys can be restored somewhat by heating them uniformly to a temperature of 1800°F to 2000°F, followed by rapid cooling to below 1000°F to 1200°F.

The visual examination of the failed burner confirmed that the fracture was brittle in nature; plastic deformation was not observed on any of the fracture surfaces. The brittle nature of the fracture was further confirmed by optical microscopy. While some cold work was detected, there was no evidence of plastic deformation. Moreover, optical microscopy revealed nearly continuous carbide and sigma phase precipitation. The higher hardness readings recorded on the burner provide additional evidence of embrittlement.

The results of the chemical analysis confirmed that the burner did not comply with the chemical composition requirements of the specified grade. Specifically, the silicon content of the burner was between 2.62% and 2.69%, significantly higher than the maximum allowable value of 2.00%. Furthermore, the nickel content of the burner was 6.8% to 6.9%, significantly lower than the allowable minimum value of 8.0% for the specified grade. While the variance of only the nickel or the silicon content would have made the burner more susceptible to sigma phase embrittlement, the combination of the two together made this burner even more susceptible.

While it is believed that erosion may also have played a role in the final failure, there is evidence to suggest that at least some of the erosion was a result of or occurred after cracking had already initiated. Furthermore, the erosion observed was not uniform, as was evidenced by the wall thickness values at areas where the localized erosion was noted during the visual examination. Moreover, erosion is to be anticipated in coal burner components and the expected service life should already reflect that fact.

Due to the possibility that the other burners in this boiler may have similar issues, it would be prudent to perform chemical analyses of those burners during the next outage.

CONCLUSIONS

Thielsch Engineering performed a metallurgical evaluation of a coal burner tip that had failed in service at the Intermountain Power facility in Delta, Utah. The results of this evaluation indicate that the failure of the burner tip was due to the improper chemical composition of the casting which was susceptible to carbide precipitation, sigma phase embrittlement and cracking when exposed to the operating temperature of between 980°F and 1505°F. Preferential and localized erosion of the burner tip had also contributed to the failure.

RECOMMENDATIONS

To ensure that the remaining burners provided by Advanced Burner Technologies were cast from the specified material grade, their chemical composition should be verified. Burners with low nickel and high silicon contents should either be removed from service, or if they have sufficient wall thickness remaining, they may be heat treated to restore their ductility.

In addition, it is recommended that nondestructive examinations be performed at the next scheduled outage to identify typical conditions of deterioration within the remaining burners. These examinations should focus on those locations that typically exhibit the most erosion.

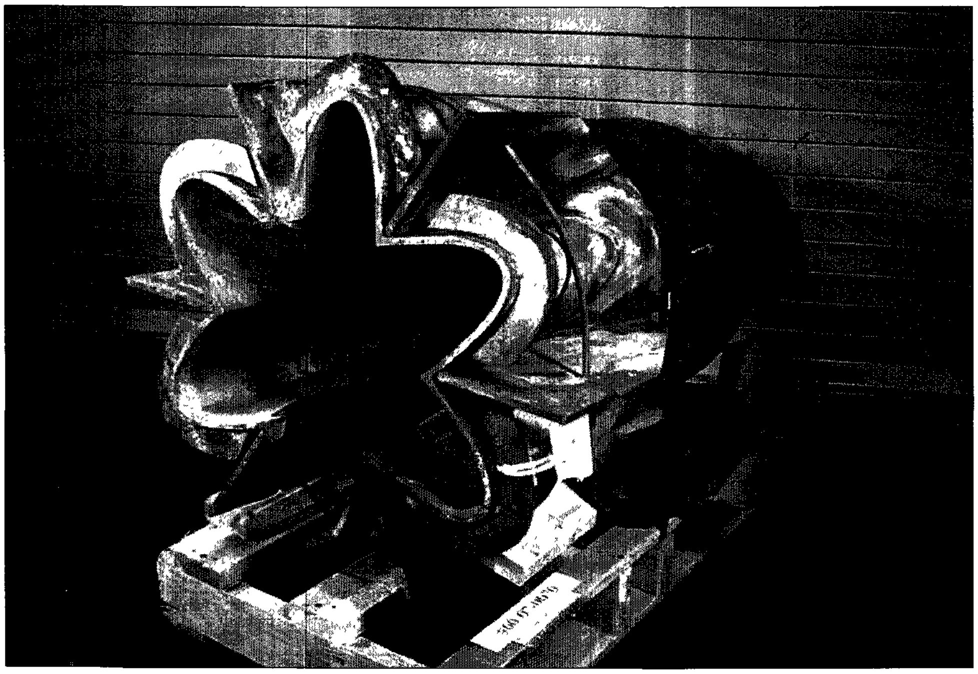


Fig. 1. Overall view of burner tip, upon receipt.

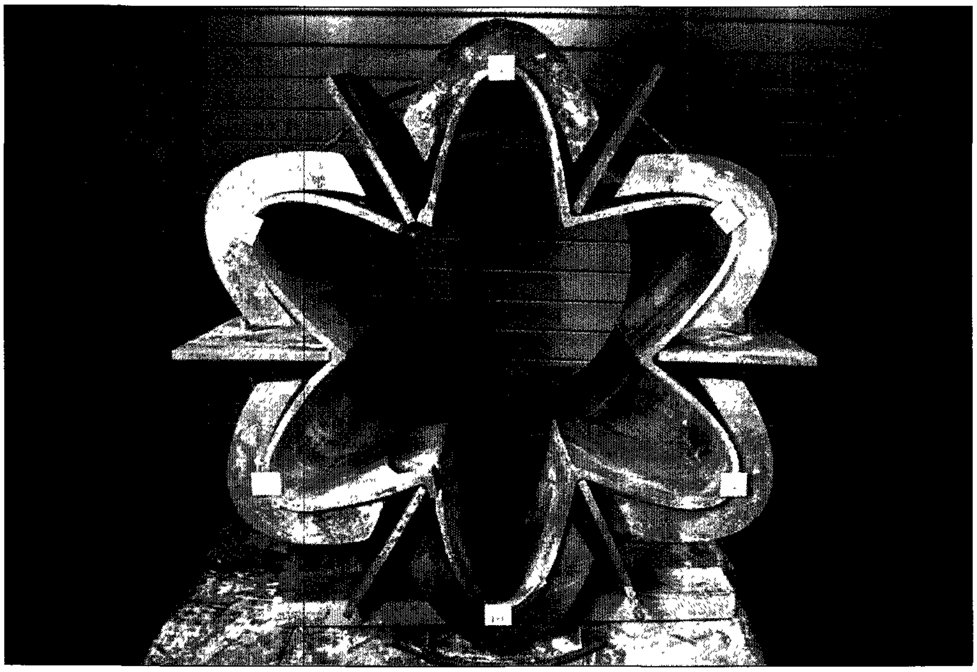


Fig. 2. Overall view of burner tip, labeled for laboratory examination.

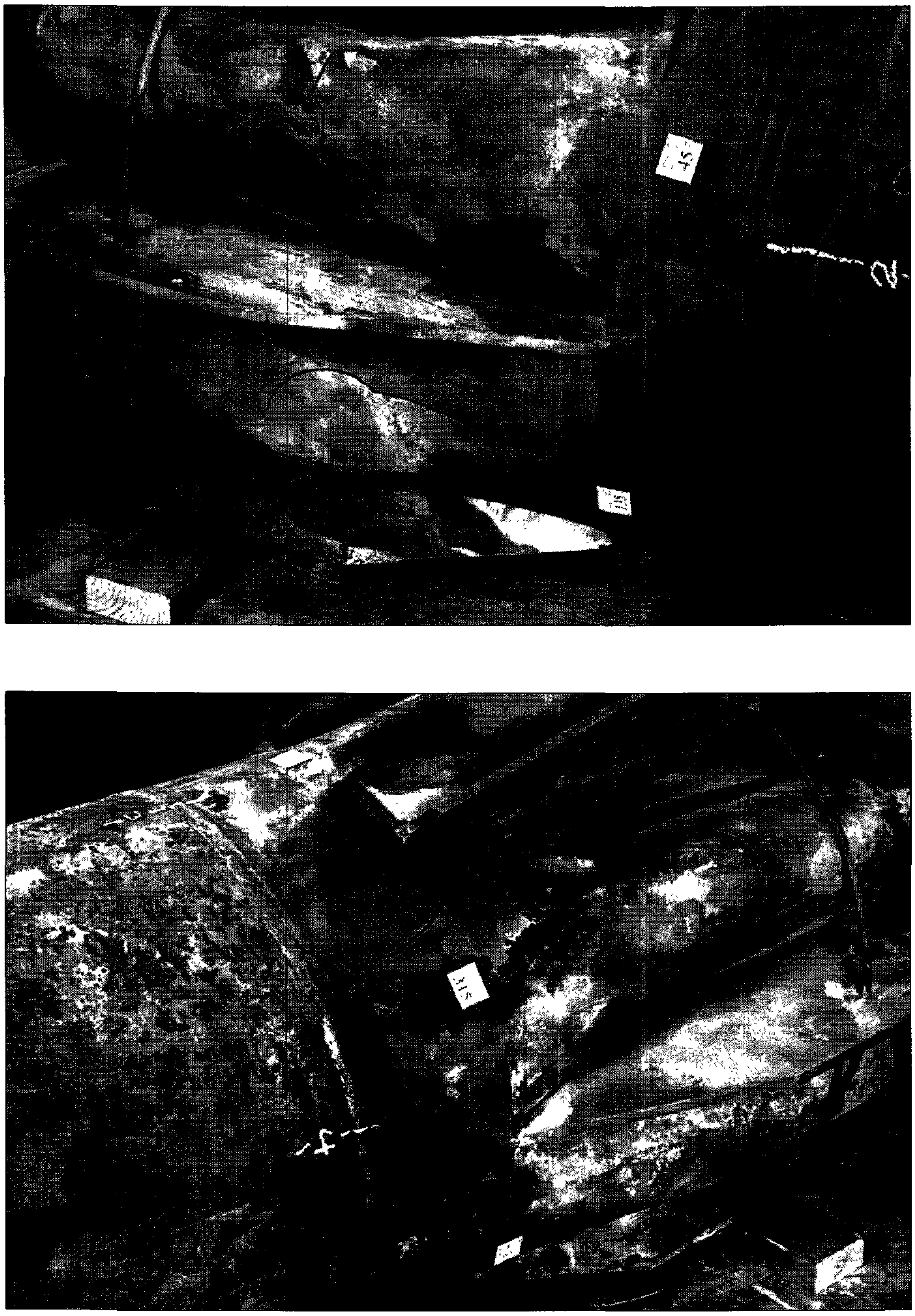


Fig. 3. Overall views of outside diameter surfaces of burner tip.

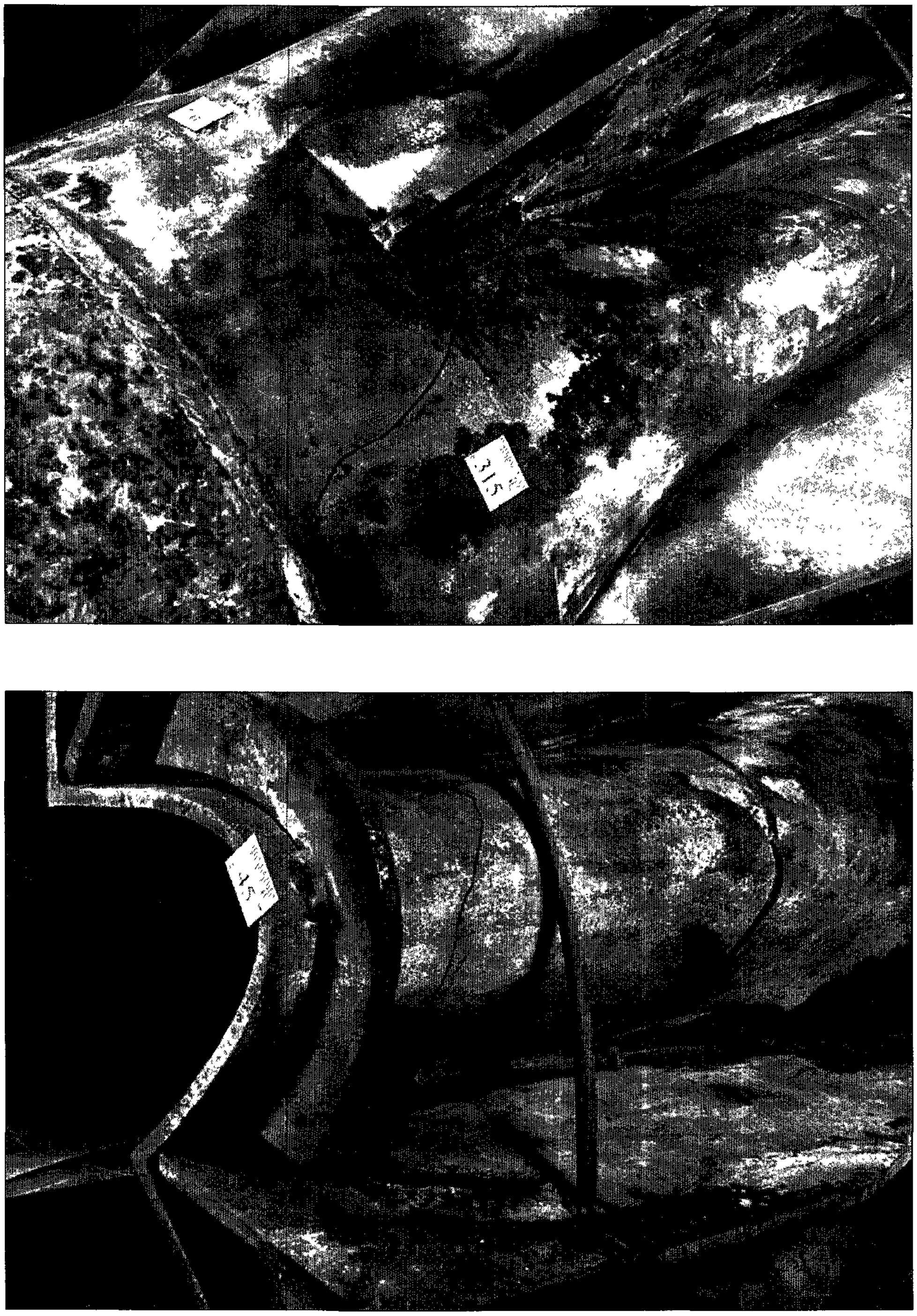


Fig. 4. Additional views of outside diameter surfaces of burner tip.

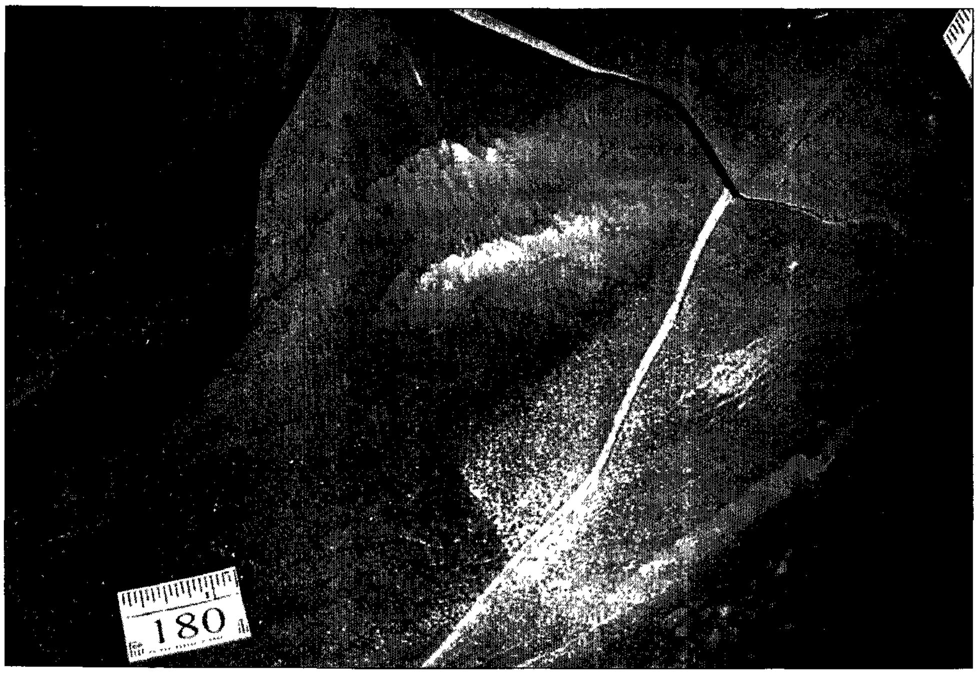


Fig. 5. Overall and close-up views of inside diameter surfaces of burner tip.

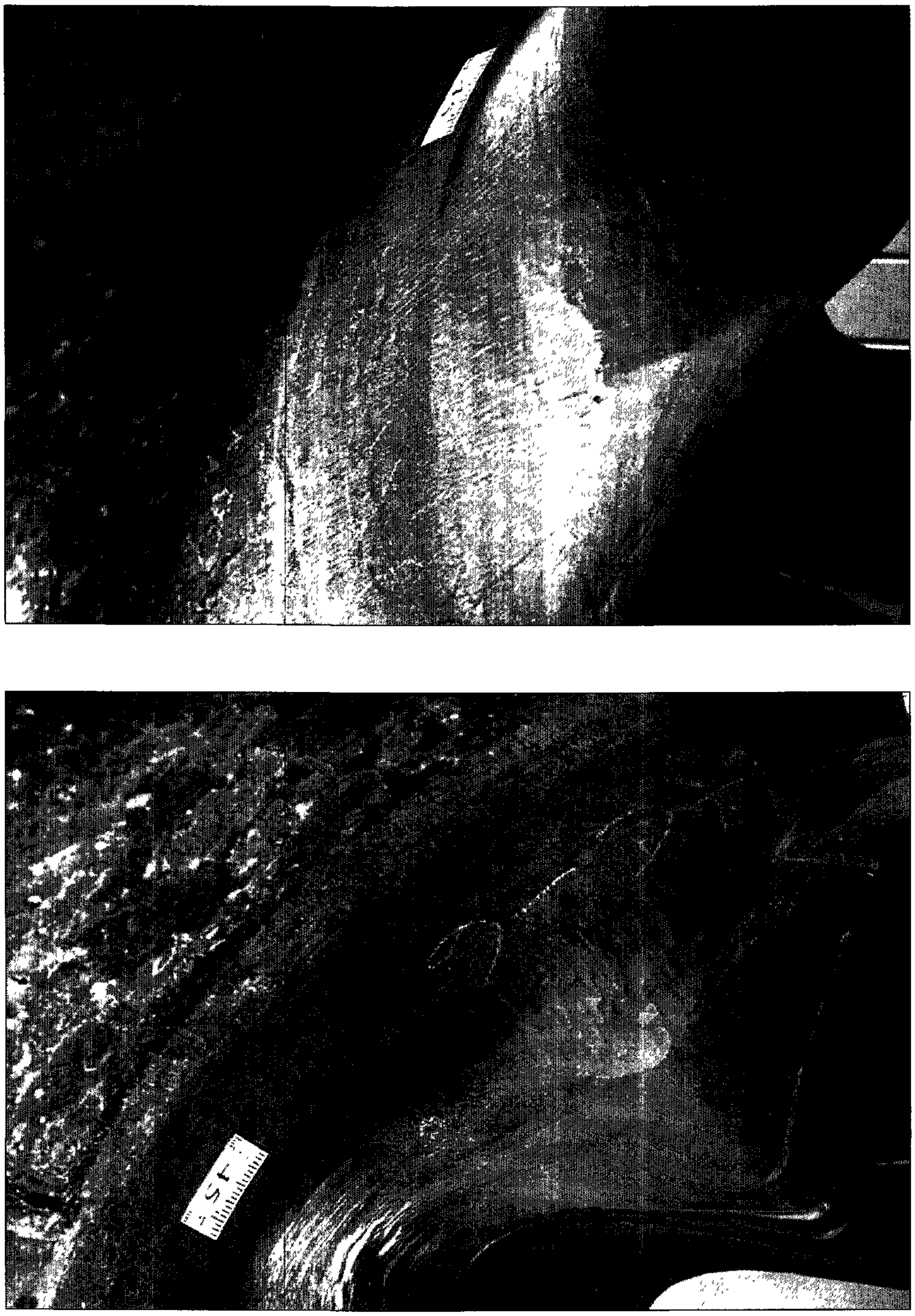


Fig. 6. Additional views of inside diameter surfaces of burner tip.

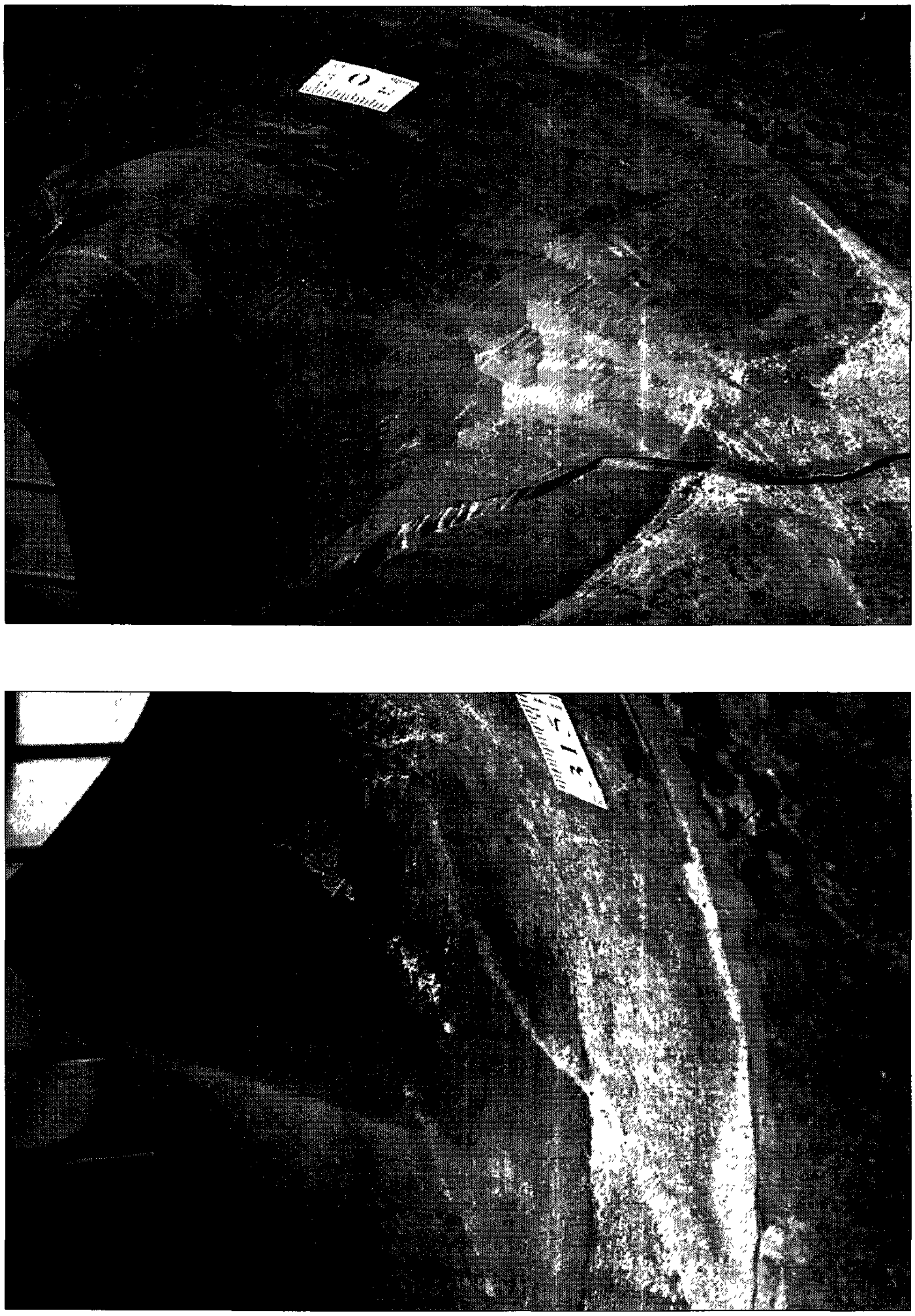
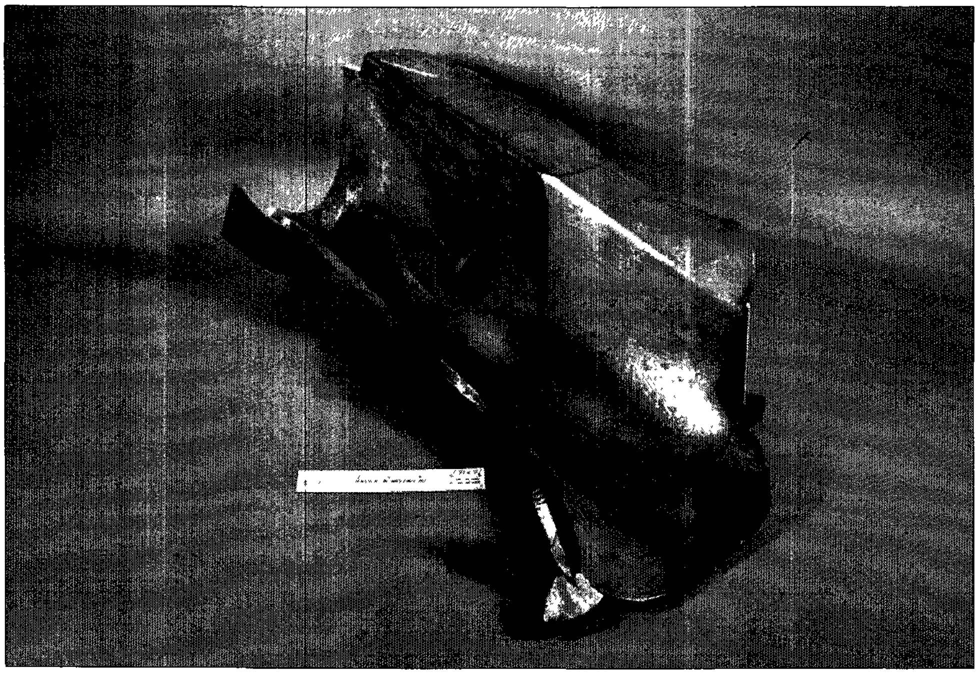
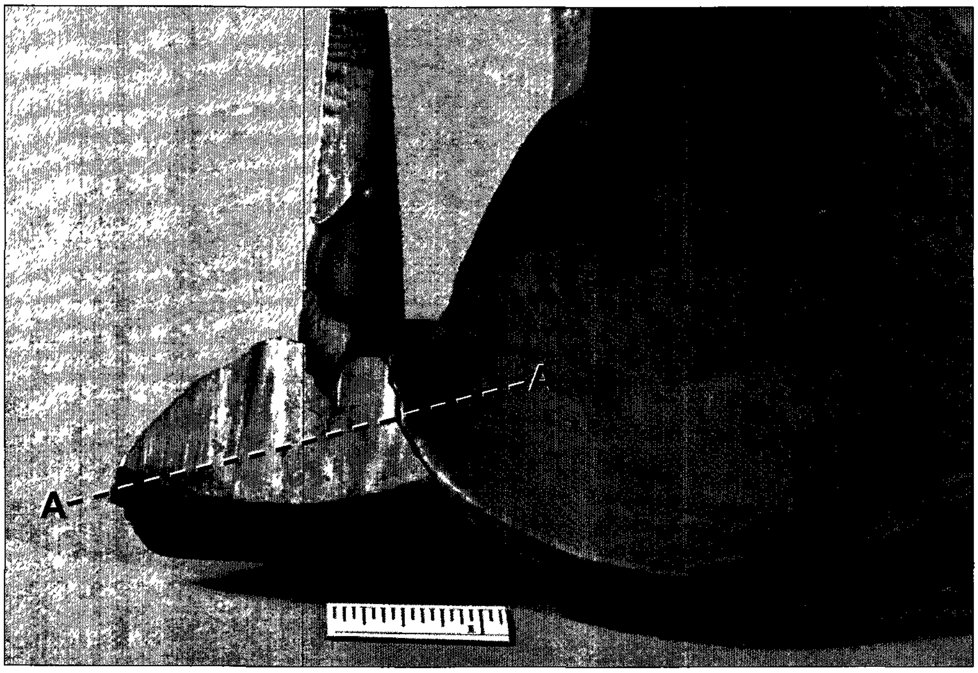


Fig. 7. Additional close-up views of inside diameter surfaces of burner tip.

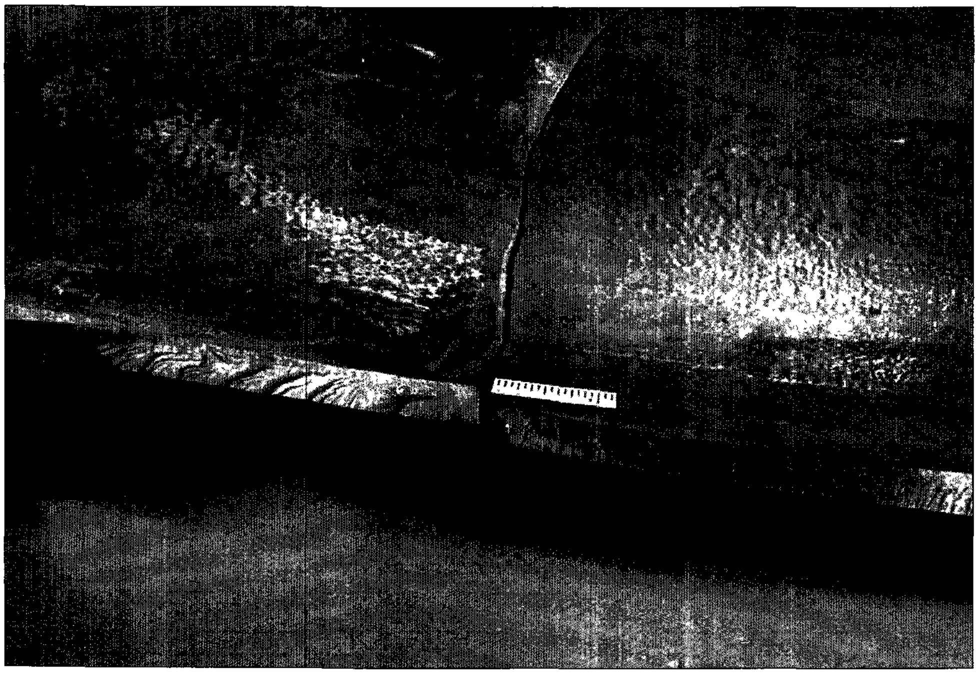


3/16X

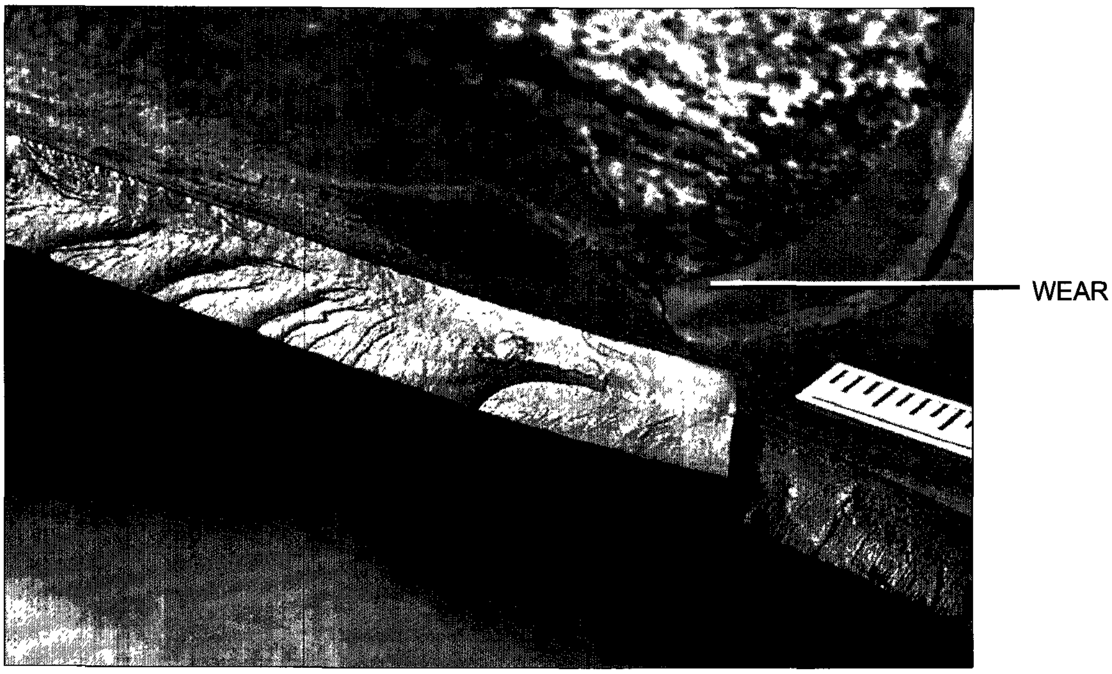


7/8X

Fig. 8. Overall and close-up views of detached segment.

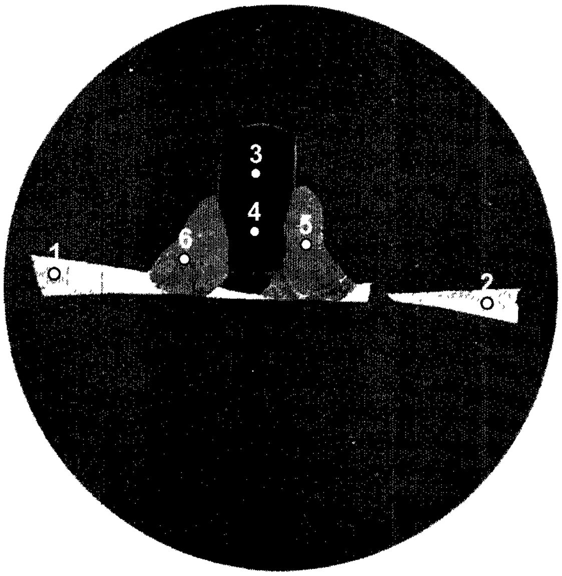


9/16X



1-7/16X

Fig. 9. Close-up views of detached segment.



1X

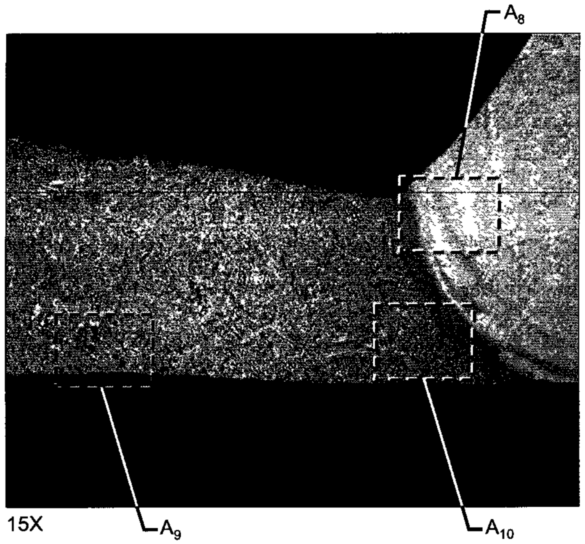
Fig. 10. Overall view of subsegment cut at cross section "A-A". Rockwell B and C hardness determinations are provided below. The corresponding Brinell hardness numbers are shown in ( ).

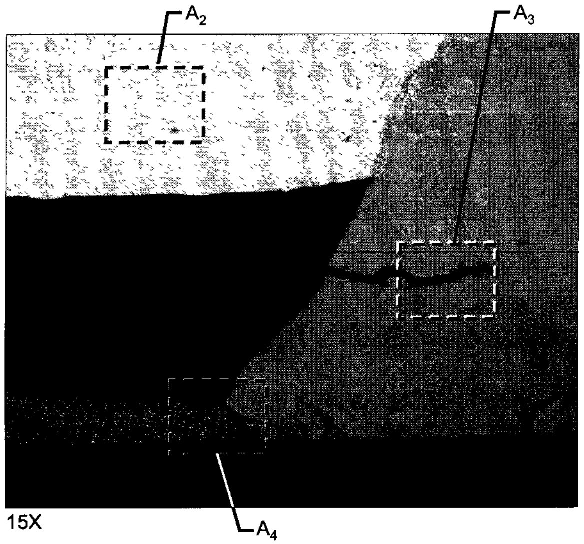
Rockwell C
Hardness Values

1. 32.6 (307)
2. 32.3 (304)

Rockwell B
Hardness Values

3. 88.7 (186)
4. 91.5 (199)
5. 95.8 (224)
6. 96.5 (229)





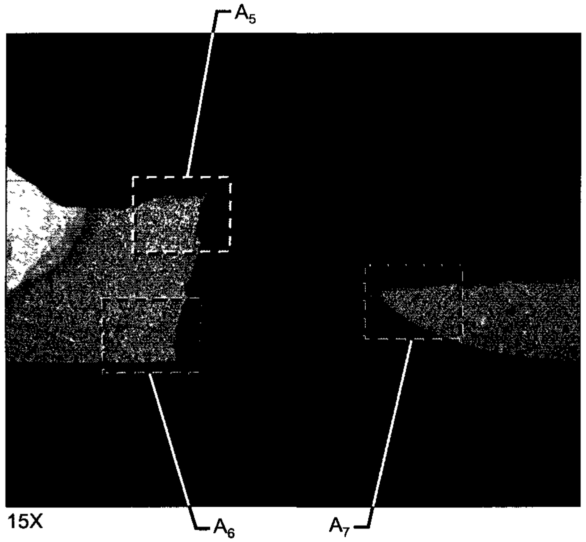
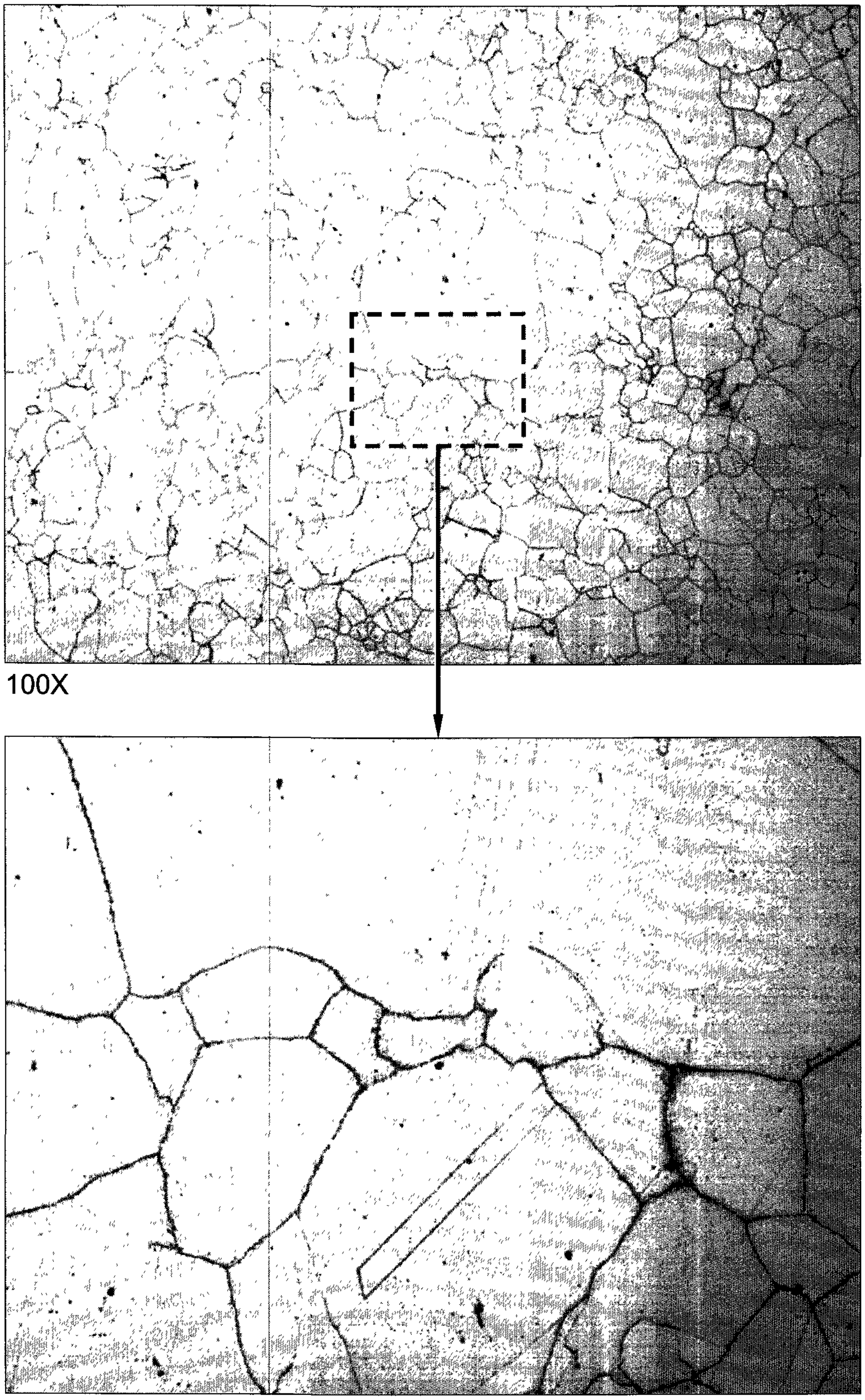


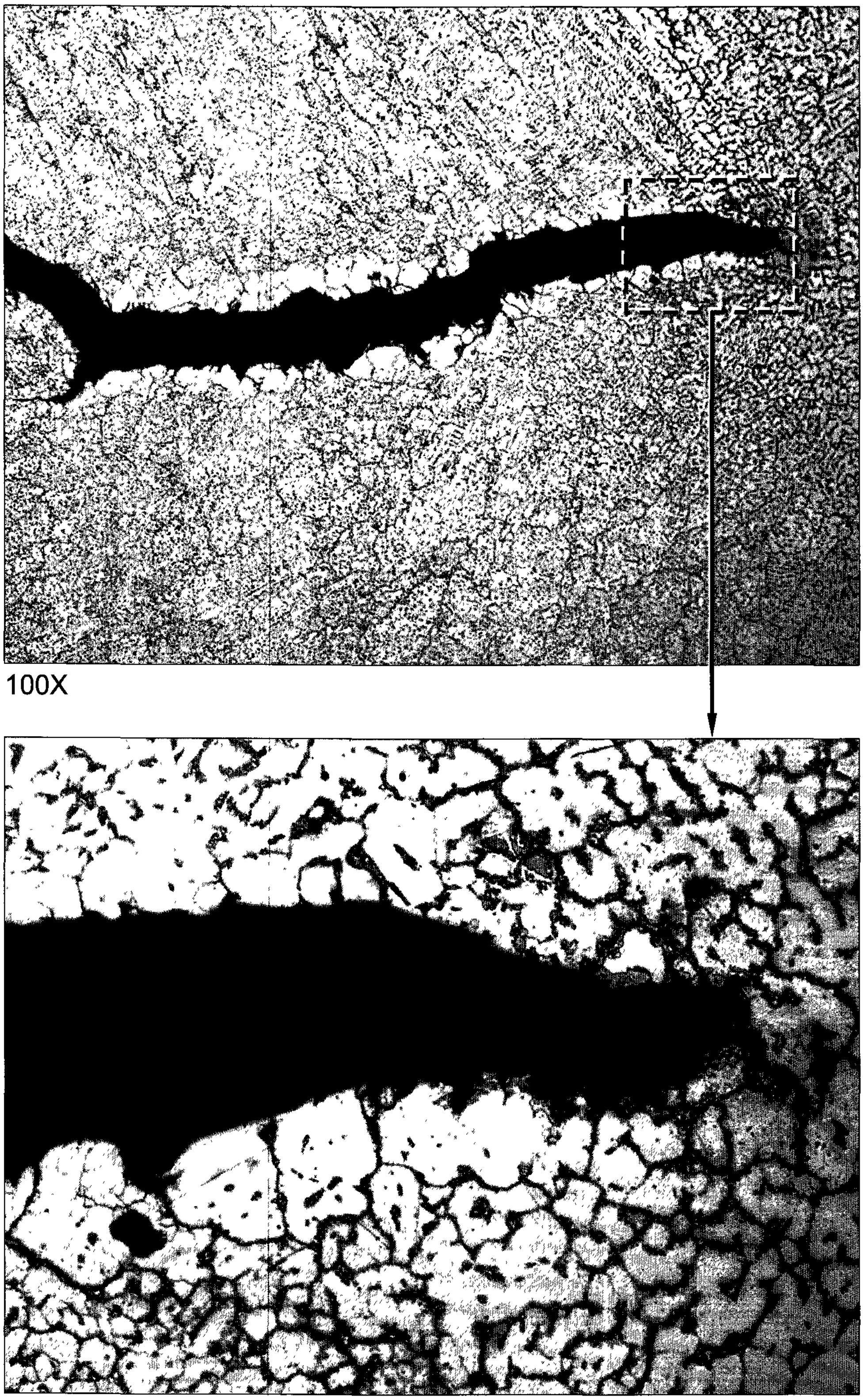
Fig. 11. Photomacrographs of cross section "A-A".



100X

500X

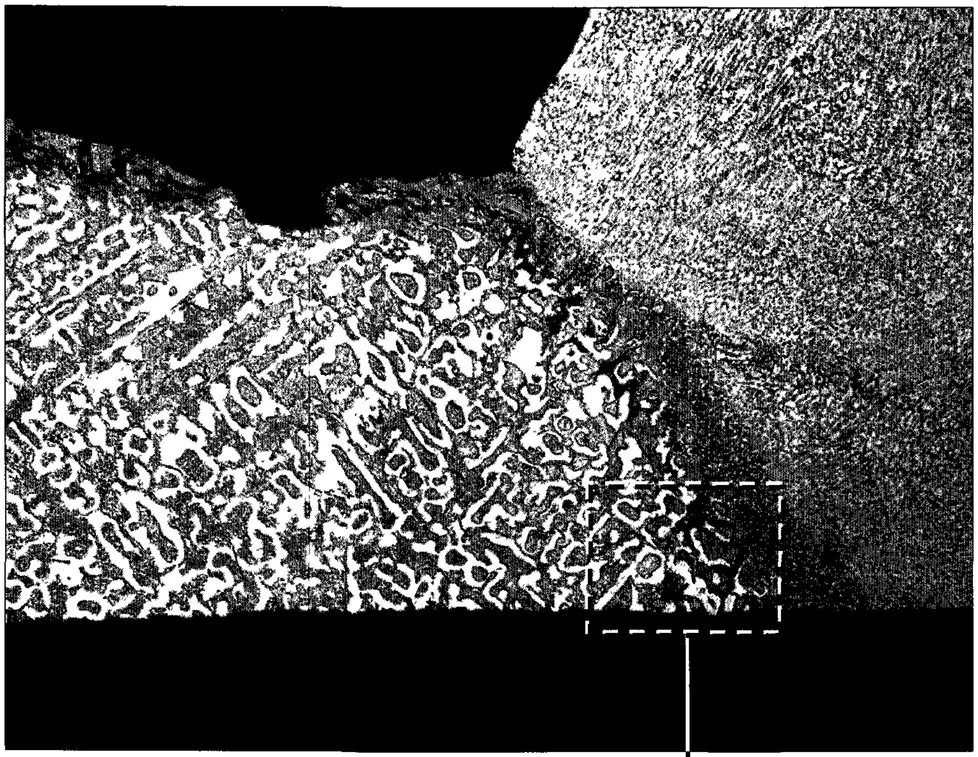
Fig. 12. Microstructure at "A_2".



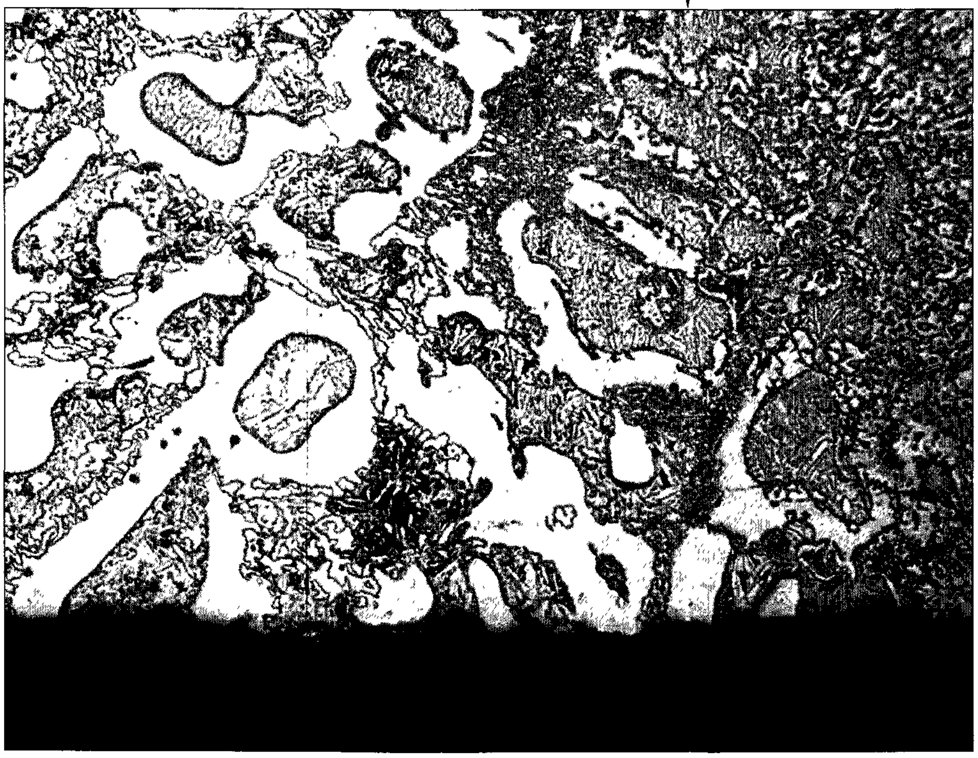
100X

500X

Fig. 13. Microstructure at "A_3".



100X



500X

Fig. 14. Microstructure at "A_4".

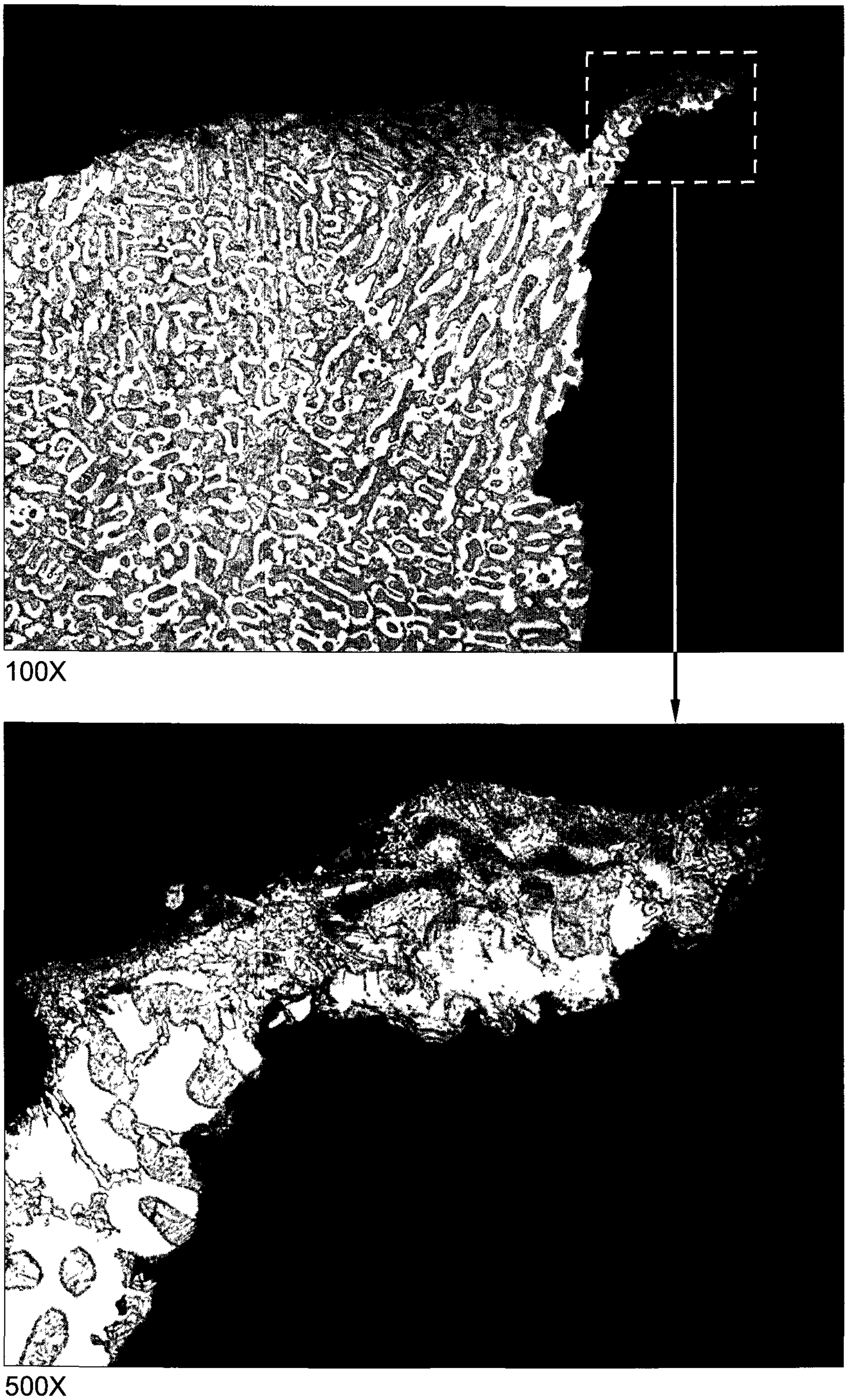


Fig. 15. Microstructure at "A_5".

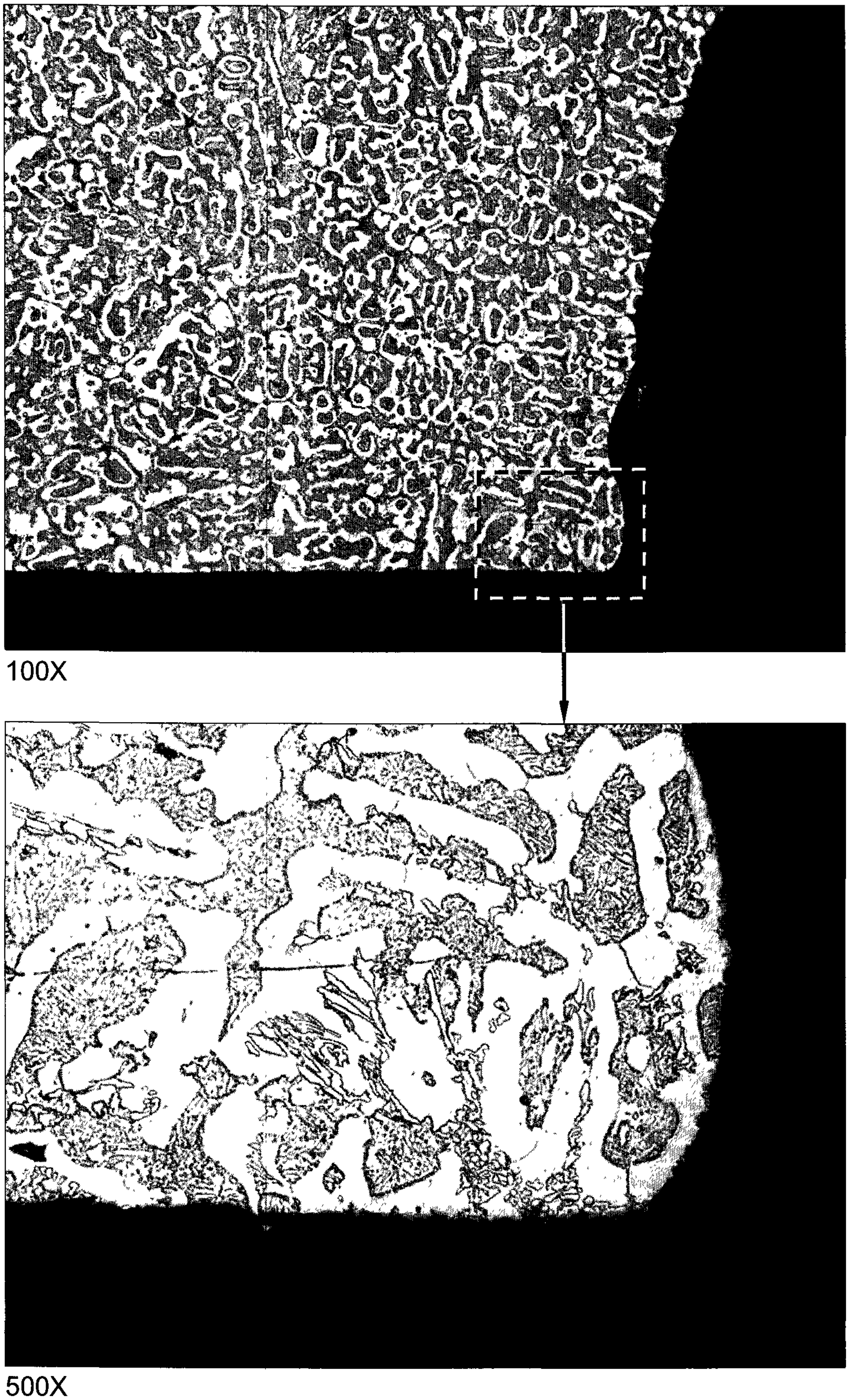
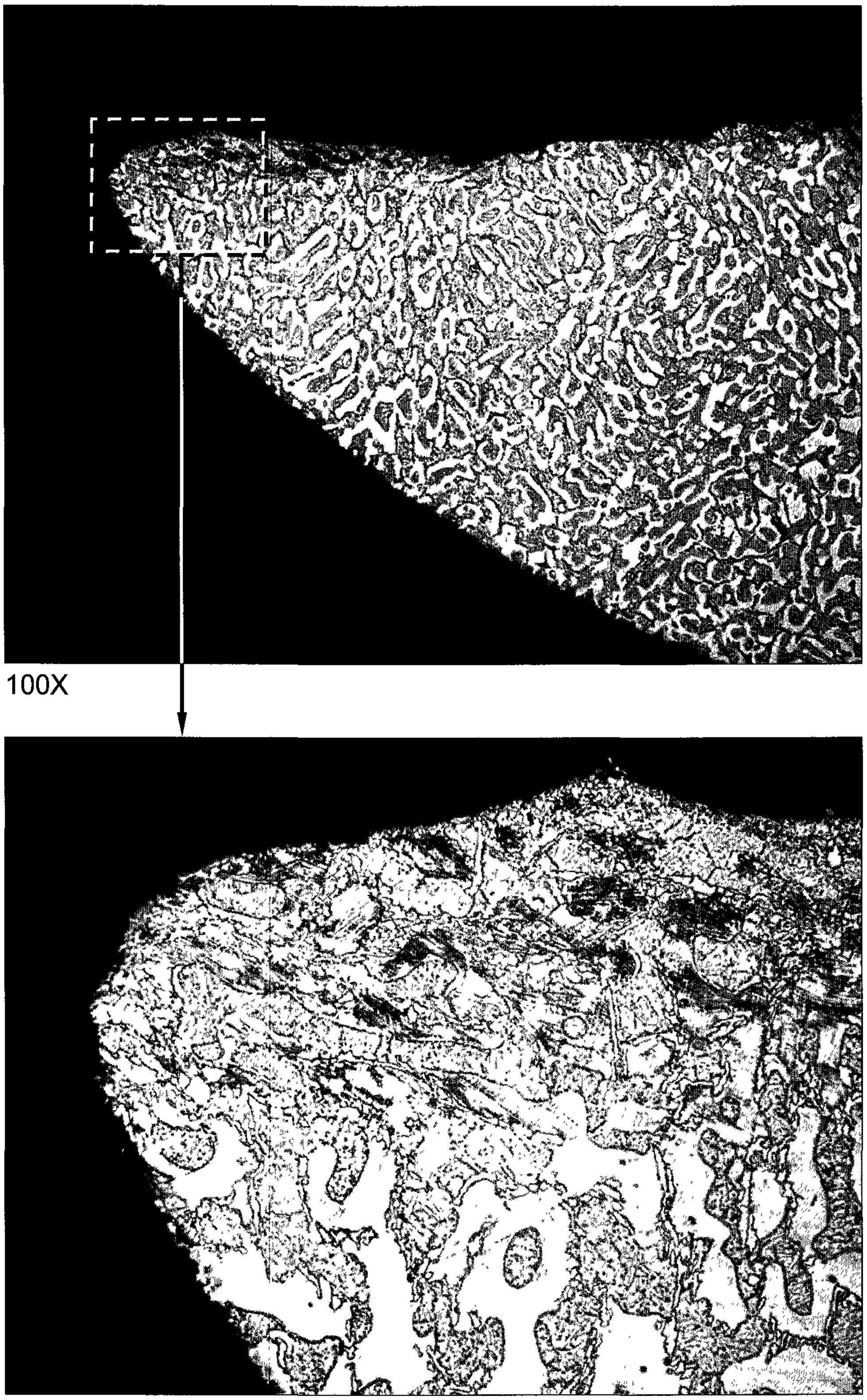


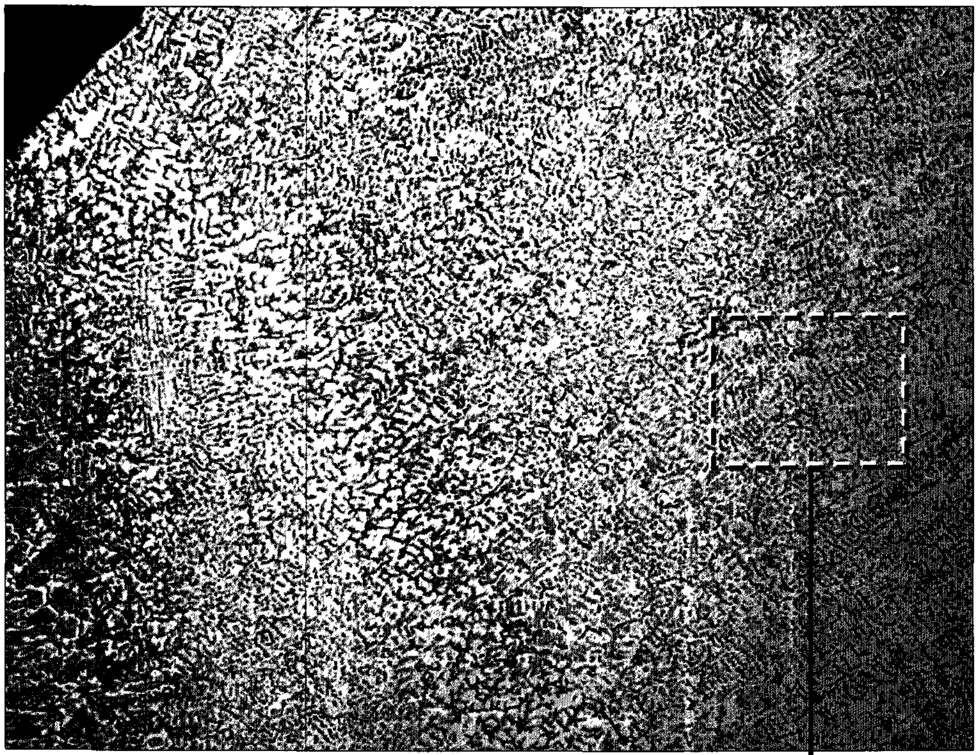
Fig. 16. Microstructure at "A_6".



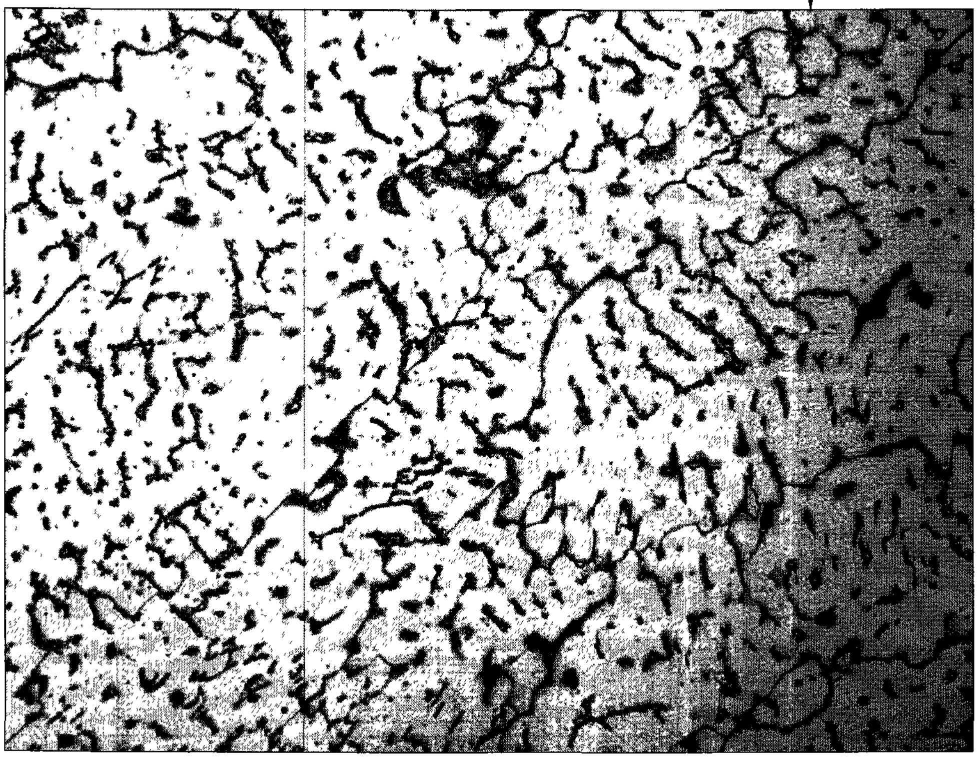
100X

500X

Fig. 17. Microstructure at "A_7".

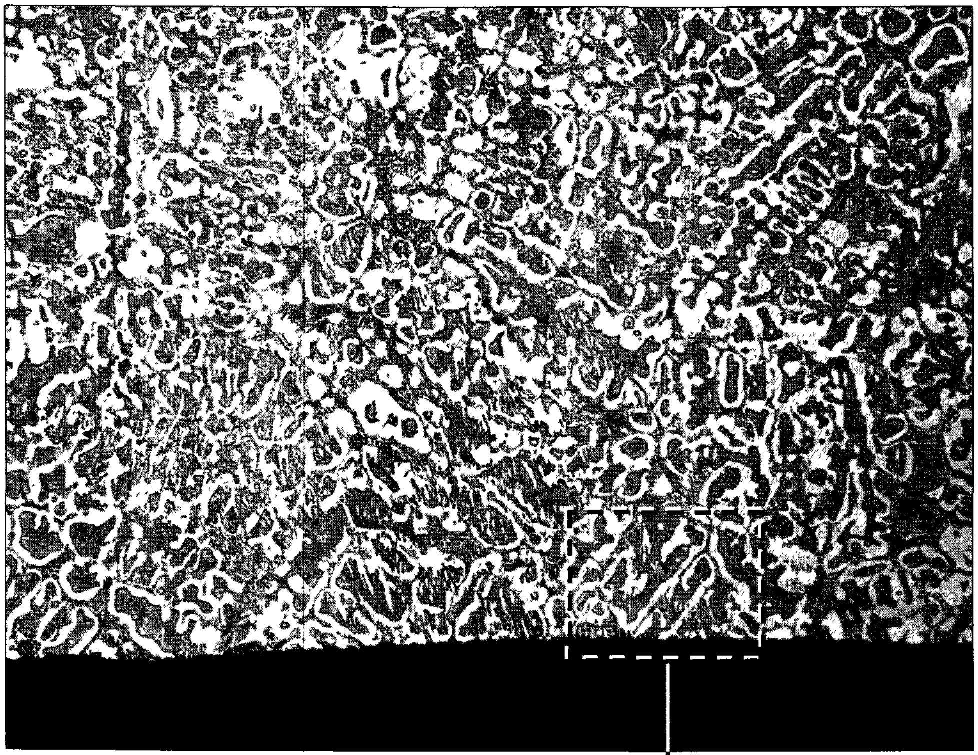


100X

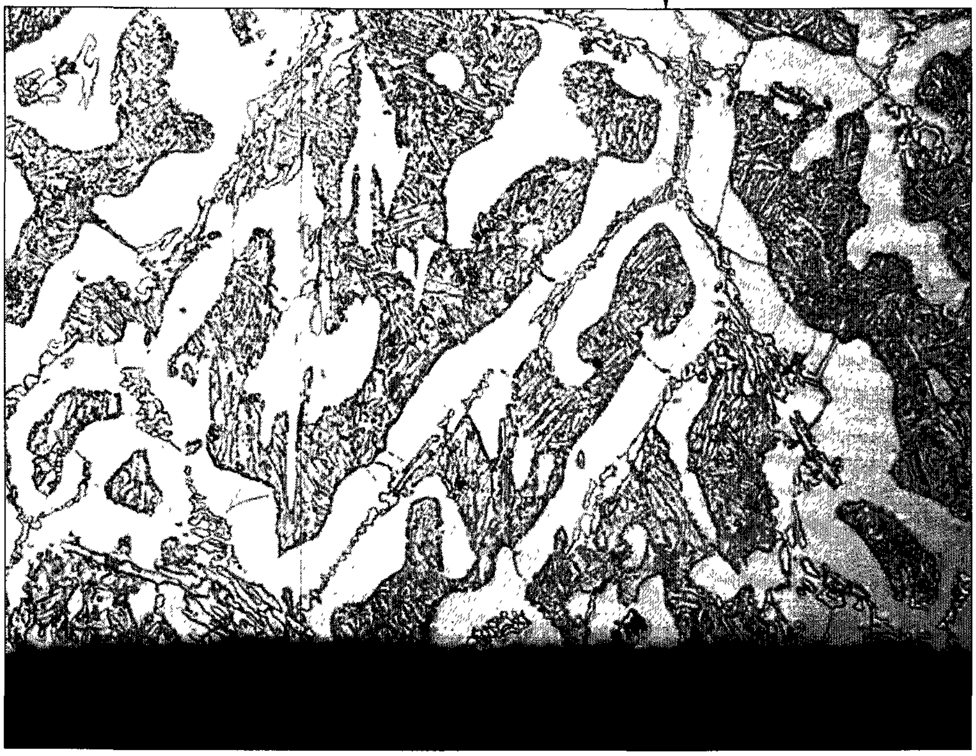


500X

Fig. 18. Microstructure at "A_8".

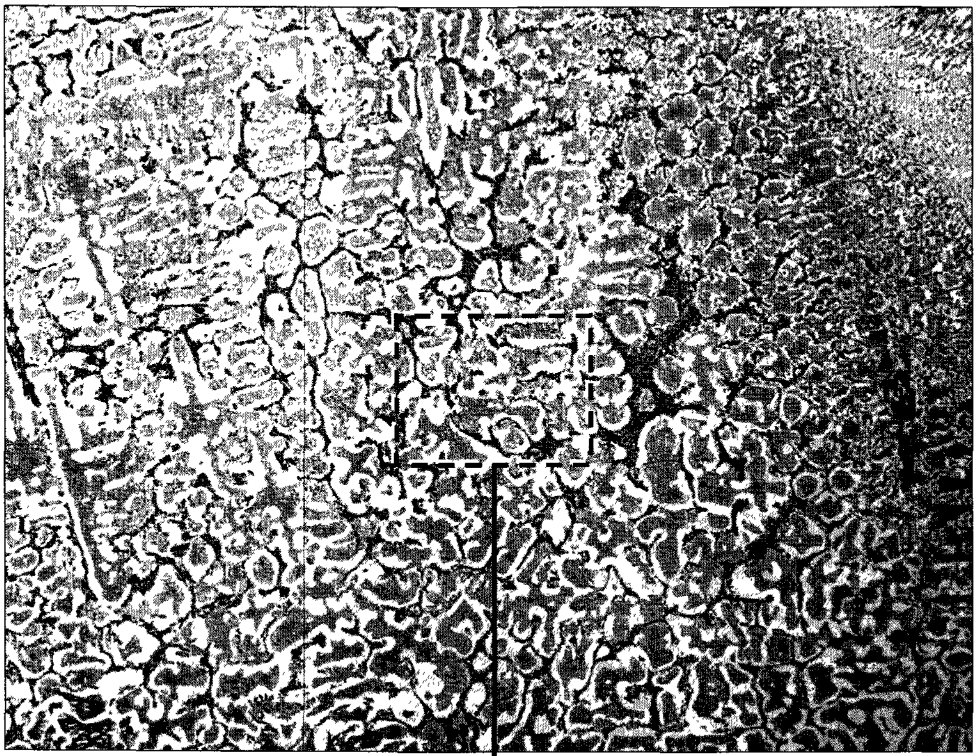


100X

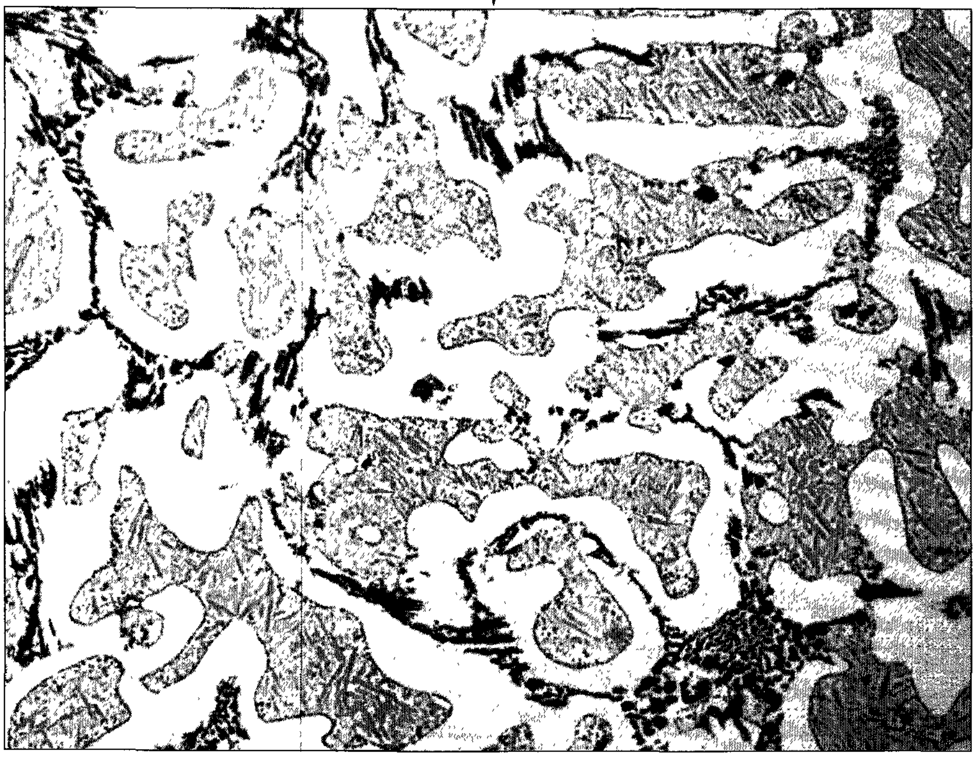


500X

Fig. 19. Microstructure at "A_9".



100X

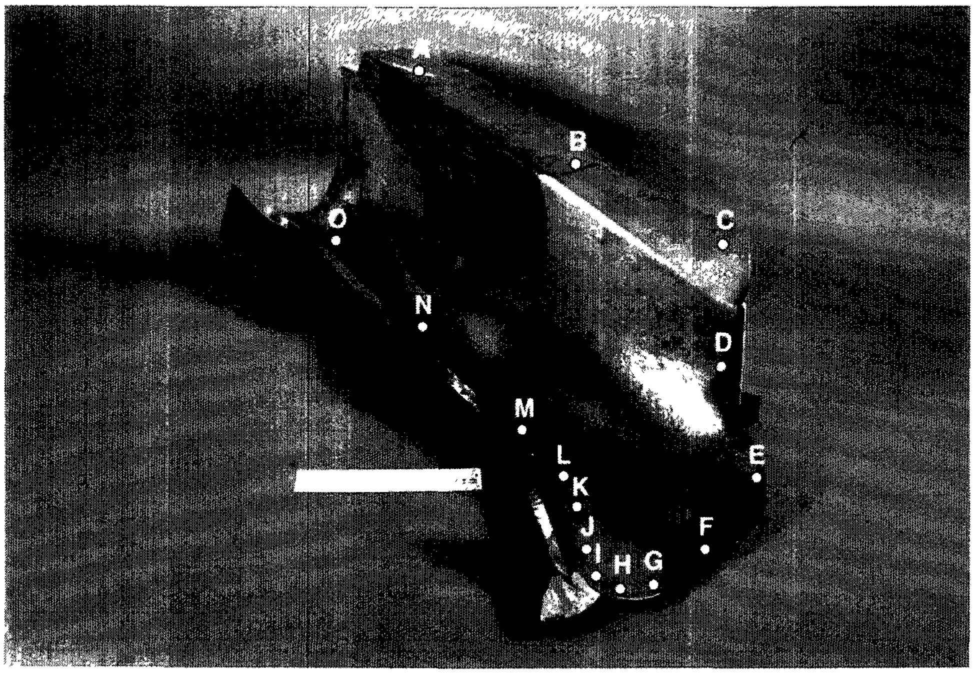


500X

Fig. 20. Microstructure at "A_{10}" subsequent to additional etching to delineate carbides and sigma phase.

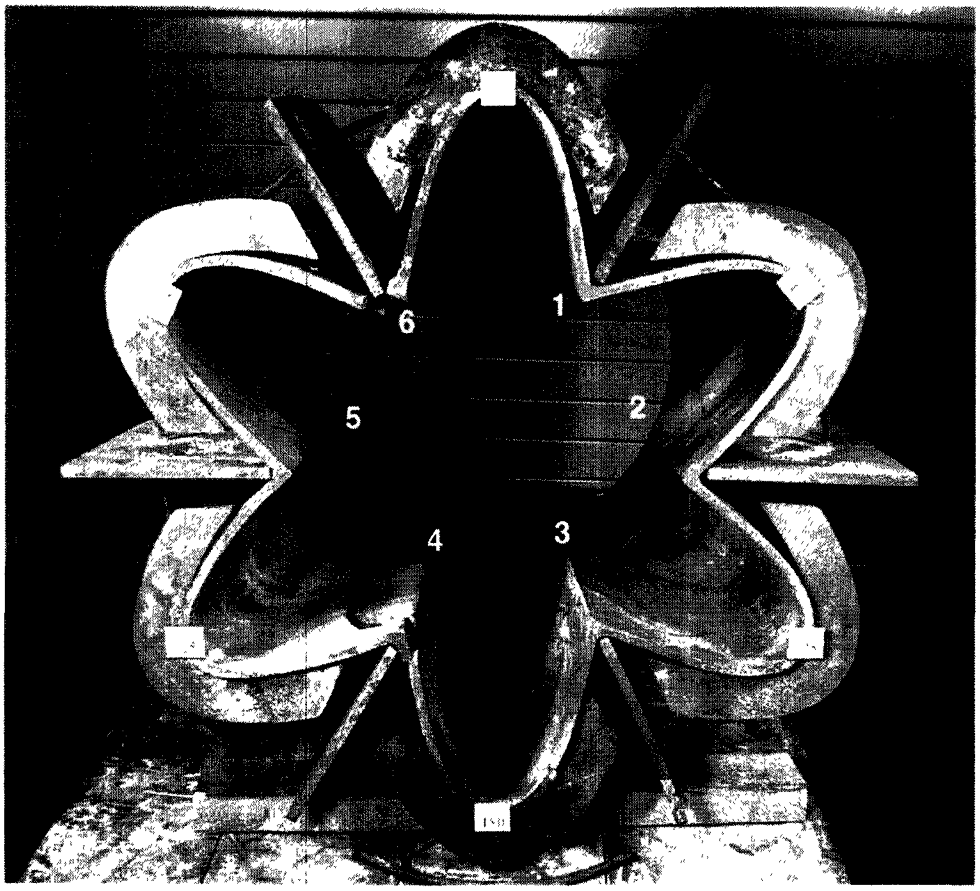
APPENDIX A

DIMENSIONAL MEASUREMENTS



FRACTURE WALL THICKNESS

A	0.350"
B	0.349"
C	0.436"
D	0.363"
E	0.414"
F	0.342"
G	0.593"
H	0.295"
I	0.099"
J	0.036"
K	0.183"
L	0.419"
M	0.444"
N	0.355"
O	0.368"



WALL THICKNESS MEASUREMENTS

LOCATION	WEAR AREA	2" ABOVE	2" BELOW
1.	0.081"	0.383"	0.256"
2.	0.112"	0.407"	0.381"
3.	0.090"	0.352"	0.382"
4.	0.111"	0.393"	0.446"
5.	0.418"	0.435"	0.410"
6.	0.145"	0.327"	0.294"

APPENDIX B

ASTM SPECIFICATION A-297

Designation: A 297/A 297M – 97 (Reapproved 1998)

AMERICAN SOCIETY FOR TESTING AND MATERIALS
100 Barr Harbor Dr., West Conshohocken, PA 19428
Reprinted from the Annual Book of ASTM Standards. Copyright ASTM

Standard Specification for Steel Castings, Iron-Chromium and Iron-Chromium-Nickel, Heat Resistant, for General Application[1]

This standard is issued under the fixed designation A 297/A 297M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers iron-chromium and iron-chromium-nickel alloy castings for heat-resistant service. The grades covered by this specification are general purpose alloys and no attempt has been made to include heat-resisting alloys used for special production application

NOTE 1—For heat-resisting alloys used for special product application, reference should be made to SpecificationA 351/A 351M, A 217/A 217M, and A 447/A 447M

1.2 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards*

A 217/A217M Specification for Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts, Suitable for High-Temperature Service[2]

A 351/A351M Specification for Castings, Austenitic, Austenitic-Ferritic (Duplex), for Pressure-Containing Parts[2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[3]

A 447/A447M Specification for Steel Castings, Chromium-Nickel-Iron Alloy (25-12 Class), for High-Temperature Service[2]

A 781/A781M Specification for Castings, Steel and Alloy, Common Requirements, for General Industrial Use[2]

3. General Conditions for Delivery

3.1 Material furnished to this specification shall conform to the requirements of Specification A 781/A 781M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 781/A 781M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 781/A 781M, this specification shall prevail.

4. Ordering Information

4.1 The inquiry and order should include or indicate the following:

4.1.1 A description of the casting by pattern number or drawing (dimensional tolerances shall be included on the casting drawing),

4.1.2 Grade of steel,

4.1.3 Options in the specification, and

4.1.4 The supplementary requirements desired including the standards of acceptance.

5. Process

5.1 Alloys shall be made by the following processes: electric-arc, electric-induction, or other approved processes.

6. Heat Treatment

6.1 Castings for heat-resistant service may be shipped in the as-cast condition without heat treatment. If heat treatment is required, the treatment shall be established by mutual agreement between the manufacturer and the purchaser and shall be so specified in the inquiry, contract, or order.

7. Chemical Composition

7.1 Alloys shall conform to the requirements as to chemical composition prescribed in Table 1.

8. Repair by Welding

8.1 The composition of the deposited weld metal shall be similar to the composition of the casting. All weld repairs shall be subjected to the same inspection standards as the casting.

8.2 Castings with major weld repairs shall be heat treated in accordance with Section 6.

8.3 Weld repairs shall be considered major when the depth of the cavity after preparation for repair exceeds 20 % of the actual wall thickness, or 1 in. [25 mm], whichever is smaller, or when the extent of the cavity exceeds approximately 10 in.^{2}[65 cm^2].

8.3.1 When Supplementary Requirement S7 is specified on the purchase order, or inquiry, major weld repairs shall be

[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings

Current edition approved Nov 10, 1997 Published October 1998. Originally published as A 297 – 46 T Last previous edition A 297/A 297M – 89.

[2] *Annual Book of ASTM Standards*, Vol 01.02.

[3] *Annual Book of ASTM Standards*, Vol 01.03.

TABLE 1 Chemical Requirements

Grade	Type	Composition, %							
		Carbon	Manganese, max	Silicon, max	Phosphorus, max	Sulfur, max	Chromium	Nickel	Molybdenum, max[A]
HF	19 Chromium, 9 Nickel	0.20–0 40	2.00	2.00	0.04	0.04	18.0–23 0	8.0–12 0	0.50
HH	25 Chromium 12 Nickel	0 20–0 50	2.00	2 00	0.04	0 04	24.0–28.0	11.0–14.0	0.50
HI	28 Chromium, 15 Nickel	0 20–0 50	2.00	2 00	0.04	0.04	26.0–30 0	14 0–18.0	0.50
HK	25 Chromium 20 Nickel	0 20–0 60	2.00	2.00	0.04	0.04	24 0–28.0	18 0–22.0	0.50
HE	29 Chromium, 9 Nickel	0 20–0 50	2.00	2.00	0.04	0.04	26.0–30 0	8 0–11.0	0.50
HT	15 Chromium, 35 Nickel	0 35–0 75	2 00	2.50	0.04	0.04	15.0–19 0	33.0–37.0	0.50
HU	19 Chromium, 39 Nickel	0 35–0 75	2.00	2.50	0.04	0.04	17.0–21.0	37.0–41.0	0.50
HW	12 Chromium, 60 Nickel	0 35–0 75	2 00	2.50	0 04	0.04	10.0–14.0	58.0–62.0	0.50
HX	17 Chromium, 66 Nickel	0 35–0.75	2.00	2.50	0.04	0.04	15.0–19.0	64.0–68.0	0.50
HC	28 Chromium	0 50 max	1.00	2.00	0.04	0.04	26.0–30 0	4.00 max	0.50
HD	28 Chromium 5 Nickel	0 50 max	1 50	2.00	0.04	0.04	26.0–30 0	4.0–7.0	0.50
HL	29 Chromium, 20 Nickel	0 20–0 60	2 00	2 00	0.04	0.04	28.0–32.0	18.0–22.0	0.50
HN	20 Chromium, 25 Nickel	0 20–0 50	2.00	2 00	0.04	0.04	19 0–23.0	23 0–27 0	0 50
HP	26 Chromium 35 Nickel	0 35–0 75	2 00	2.50	0.04	0.04	24–28	33–37	0.50

[A]Castings having a specified molybdenum range agreed upon by the manufacturer and the purchaser may also be furnished under these specifications.

subject to the prior approval of the purchaser.

8.4 All other weld repairs shall be considered minor and may be made at the discretion of the manufacturer without prior approval of the purchaser.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 781/A 781M. Those which are ordinarily considered suitable for use with this specification are given below. Others enumerated in A 781/A 781M may be used with this specification upon agreement between the manufacturer and purchaser.

S1. Magnetic Particle Examination

S2. Radiographic Examination

S3. Liquid Penetrant Examination

S4. Ultrasonic Examination

S5. Examination of Weld Preparation

S6. Certification

S7. Prior Approval of Major Weld Repairs

S8. Marking

S9. Tension Test

S9.1 One tension test shall be made from material representing each heat. The bar from which the test specimen is taken shall be heat treated in production furnaces to the same procedure as the castings it represents. The results shall conform to the requirements specified in Table S9.1.

S9.2 Test bars shall be poured in separately cast keel blocks similar to Fig. 3 of Test Methods and Definitions A 370 or Fig.1 of Specification A 447/A 447M.

S9.3 Tension test specimens may be cut from heat-treated castings; or from as-cast castings if no heat treatment is specified for the castings, instead of from test bars when agreed upon between the manufacturer and the purchaser.

S9.4 Test specimens shall be machined to the form and dimensions of the standard round 2-in. [50-mm] gage length specimen shown in Fig. 6 of Test Methods and Definitions A 370 and shall be tested in accordance with Test Methods and Definitions A 370.

TABLE S9.1 Tensile Requirements

Grade	Type	Tensile Strength, min		Yield Point, min		Elongation in 2 in. [50 mm], min, %[A]
		ksi	[MPa]	ksi	[MPa]	
HF	19 Chromium, 9 Nickel	70	485	35	240	25
HH	25 Chromium, 12 Nickel	75	515	35	240	10
HI	28 Chromium, 15 Nickel	70	485	35	240	10
HK	25 Chromium, 20 Nickel	65	450	35	240	10
HE	29 Chromium, 9 Nickel	85	585	40	275	9
HT	15 Chromium, 35 Nickel	65	450	...	...	4
HU	19 Chromium, 39 Nickel	65	450	...	...	4
HW	12 Chromium, 60 Nickel	60	415	...	...	...
HX	17 Chromium, 66 Nickel	60	415	...	...	...
HC	28 Chromium	55	380	...	...	...
HD	28 Chromium, 5 Nickel	75	515	35	240	8
HL	29 Chromium, 20 Nickel	65	450	35	240	10
HN	20 Chromium, 25 Nickel	63	435	...	...	8
HP	26 Chromium, 35 Nickel	62.5	430	34	235	4.5

[A]When ICI test bars are used in tensile testing as provided for in this specification, the gage length to reduced section diameter ratio shall be 4 to 1.

S9.5 If the results of the mechanical tests for any heat do not conform to the requirements specified, the castings may be re-heat treated and re-tested, but may not be solution treated or re-austenitized more than twice.

S9.6 If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted from the same heat.